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Effectiveness of Exercise-Based Rehabilitation for the Treatment of Axial Rigidity in People with Parkinson's Disease: *A Scoping Review*

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Abstract

Background: Axial rigidity is a common symptom in people with Parkinson's disease (PD) and is believed to contribute towards mobility problems and leads to an increased risk of falling. To date, effective treatment interventions to improve axial rigidity in PD have yet to be confirmed. Therefore, the aim of this scoping review was to identify and summarize the findings of exercise-based rehabilitation that have been successfully used to reduce axial rigidity in people with PD.

Methods and analysis: Ninety-four studies from the following databases were identified systematically: Cochrane Library, PEDro, Scopus, Web of Science and PubMed. Articles comparing the effects of exercise-based treatment as an experimental intervention with a non-physiotherapy intervention as the control were described using the synthesis method.

Results: Four out of eleven studies eligible for inclusion focussed explicitly on exercise-based treatment for axial rigidity in people with PD. Two studies suggested beneficial results of exercise in improving axial rigidity as evidenced by: improvement in the Unified Parkinson's Disease Rating Scale (UPDRS), axial rotation range, spinal flexibility and motion of the neck and trunk. Three further studies provided evidence for improvement of functional problems related to axial rigidity.

Conclusion: The information about exercise-based rehabilitation for axial rigidity in people with PD is very limited. This review suggests that interventions aimed at reducing axial rigidity yield positive outcomes on functional performance i.e. improve trunk mobility, turning, balance and gait patterns, as well as reducing the risk of falls in people with PD. However, the association between axial rigidity and performance following specific exercise treatments has not been explored. Furthermore, there is still a lack of evidence for the effectiveness of specific home-based exercise programmes on alleviating axial rigidity in people with PD. Therefore, there is a need for well-designed large-scale studies to elucidate these questions.

Keywords: Functional Performance; Trunk Mobility; the Unified Parkinson’s Disease Rating Scale; Exercise

Word count: 3153 excluding abstract and references

Introduction

Parkinson’s disease (PD) is a neurodegenerative movement disorder [1]. Dopaminergic medication is the first management used to alleviate symptoms of PD, but it cannot eliminate motor problems entirely and may lead to partial deterioration of movement functions [2-4]. Given the limitations of dopaminergic medication, physiotherapy is usually recommended for alleviating symptoms and coping with motor control problems [5-7]. Physiotherapy has been proven to be beneficial for individuals with PD in terms of mobility, posture, upper limb function, strengthening, balance, gait and functional performance. This can be achieved through a wide range of techniques, including treadmill training, exercising, cueing strategies, cognitive strategies, dancing and martial arts to optimise the patient’s independence, safety and well-being, decreasing the risk of falling and enhancing quality of life (QOL) [7-10].

Recently, the benefits of physiotherapy for improving movement performance and quality of life in people with PD has been established. Increasingly, evidence shows that exercise alleviates the motor symptoms of people with PD [3, 7-16].

Axial rigidity is the most visible symptom with respect to the clinical manifestation of PD, causing patients to experience difficulty while adapting movements [6, 17, 18]. Franzén et al. (2009 and 2012) reported that the tone of the neck and trunk muscles plays an essential role in controlling postural balance, mobility and coordination [19, 20]. Furthermore, evidence suggests that loss of axial mobility might contribute to functional limitations in people with PD, such as supine to sitting, reaching and turning while standing [5, 21]. Moreover, axial rigidity has been suggested to contribute to the risk of falling and quality of life among people with PD [6, 17, 18, 22-26].

The results of the aforementioned studies suggest that the positive effects of physiotherapy on functional performance in people with PD might be due to a reduction in axial rigidity. However, the existing knowledge about the effective treatment interventions on improvement of axial rigidity in PD has not yet been explored. A scoping approach offers a feasible means of collecting and synthesising a wide range of evidence to achieve this, being particularly useful to bring together evidence from heterogeneous sources [3, 5, 7, 10, 12, 16, 21, 27-29]. Therefore, the aim of this scoping review was to identify and summarize the findings of exercise-based rehabilitation that have been used to reduce axial rigidity in people with PD.

Materials and Methods

The scoping review aimed to identify, understand, summarise and disseminate the findings from a broad body of literature about the therapeutic effects of exercise on reducing axial rigidity in people with PD. The scoping review protocol was based on Arksey and O'Malley (2006) [30] and Triggo et al. (2018) [31], and included studies published in English. The methodology included five steps: (1) identifying the research question, (2) identifying studies relevant to the research question, (3) selecting studies, (4) charting information and data within the included studies and (5) collecting, summarising and reporting the results.

Step 1: Identifying the research question

The research question “Is exercise-based rehabilitation effective for the treatment of axial rigidity in patients with Parkinson’s disease?” guided this scoping review. To formulate a structure for the research question, the PICOT method was employed to address the search strategy design [27]. The population was “idiopathic PD stage 1 to 4 assessed using the Hoehn and Yahr staging scale [1]”. The intervention, “exercised-based rehabilitation”, was defined as planned, structured, repetitive and purposive activity for improvement of axial rigidity. The control group was defined as “usual care, education or medication only”, i.e. not receiving any physiotherapy. The outcome was “rigidity outcomes”, defined as those relating to rigidity, including both clinical and laboratory outcomes, i.e. UPDRS rigidity score, flexibility, range of motion (ROM) and functional axial movement tasks. The time frame adopted was “literature from 1989 to 2019”.

Step 2: Identifying relevant studies

To ensure a comprehensive literature search, the following licensed databases were used to search for peer-reviewed articles: Cochrane Central Register of Controlled Studies (CENTRAL) (*The Cochrane Library*; 1989 to December 2019), PubMed (last searched December 2019), PEDro (last searched December 2019), Scopus (1989 to December 2019) and Web of Science (last searched December 2019). Hand searching was included for more relevant citations to ensure a comprehensive search.

Thereafter, the keywords were identified based on the review of the relevant literature and the consensus of the authors. The keywords probed three main categories: (1) Parkinson’s disease, (2) physiotherapy, intervention, exercise, rehabilitation or physical therapy and (3) rigidity, stiffness, rotation, flexibility or range of motion (the logical structure keywords searching is attached in Appendix 1).

Step 3: Study selection and identification

After completing all database searches, the citations were compiled and entered into EndNote X7.7.1 bibliographic manager to remove duplicate citations. Two out of four authors independently read the titles and screened the abstracts of potentially relevant studies. They eliminated obviously irrelevant studies, with the full paper being obtained if the abstract did not provide sufficient information to determine eligibility for inclusion in the review. Based on the inclusion criteria, two review authors independently categorised these studies as "relevant", "irrelevant" or "possibly relevant". Any disagreement was resolved by the rest of the authors. Furthermore, authors of potentially eligible studies were contacted for further information if the details of their studies were unclear.

Step 4: Charting the information and data

Two out of four authors independently assessed the eligible papers or abstracts for study details and outcome data. These were then validated through discussion. Discrepancies were resolved by consensus. The study details were recorded on a standard study description form, which included the following: authors, year of publication, source of origin, aims, sample size, methodology, intervention type and comparator, concept and duration of the intervention. The outcome data that was extracted included UPDRS rigidity score, axial range of motion, flexibility outcomes, turning and gait characteristics related to axial movement performance. Additionally, authors of any eligible unpublished studies were contacted to provide further details and data related to their studies.

Step 5: Collating, summarising and reporting

Following data extraction, a narrative synthesis was conducted to describe the articles. Overall, an exercise-based rehabilitation focussing on reducing axial rigidity met the criteria that was used to identify, summarise and disseminate the research findings.

INSERT FIGURE 1

Results

2,215 results were retrieved from all sources. Duplicates were removed (n = 1,017), yielding 1,1981 for records screening and 1,017 records for eligibility screening, respectively. Thereafter, the abstracts of each study were screened, resulting in the exclusion of 1,003 papers. Fourteen articles were read in full and assessed for eligibility. Thus, only four studies were available for inclusion in the review (see Figure 1).

Details of study design of the articles reviewed

Four papers published were found to match with the criteria and then, selectively included in this scoping review (see Table 1 for a summary). Two papers described randomised controlled trials (RCTs) [17, 29] and the other described studies with a parallel group design [7, 30]. These studies were conducted in the United States (n = 2), Italy (n = 1) and Poland (n = 1).

Three studies involved participants diagnosed with PD by a neurologist. Two of these studies targeted participants with mild to moderate PD (Hoehn and Yahr 1.5-3). Only one study included participants with severe PD (Hoehn and Yahr 4).

The number of participants for all four papers ranged from 27 to 61 (17–29 men, 10–32 women), and their age ranged from 55 to 85. The Hoehn & Yahr stage ranged from 1.5 to 4. The duration of the interventions ranged from 4 to 12 weeks.

Details of exercise intervention within the included articles

Details of exercise prescription include type of exercise, intensity of exercise and duration of exercise, described in Table 1.

Schenkman et al. (1998) compared the effects of an axial mobility exercise programme with a control group who received usual care [5]. They studied 51 participants. The study design was an RCT. Thirty treatment sessions were conducted over 10 weeks. The exercise programme was based on the concept that improved muscle length and coordination can be achieved when people are taught to move in a relaxed manner with synergetic activation of appropriate muscles groups.

Bartolo et al. (2010) compared the effects of a rehabilitation programme with a control group who received medication [32]. They studied 22 participants and used a parallel group design. The treatment sessions were regular, individual, 90-minute sessions conducted over four weeks. The rehabilitation programme included cardiovascular warm-up, stretching exercises, strengthening exercises, overground gait training, balance training and relaxation exercises.

Stozek et al. (2016) studied 61 participants [24]. The study employed a parallel group design. Participants were randomly allocated into two groups; a rehabilitation or control group with usual care. The treatment sessions, consisting of 28 therapy sessions, lasted for four weeks. Each session lasted for two hours with breaks, held twice per day during the first two weeks. During the two consecutive weeks, the sessions were conducted three times a week with one session per day. The intervention was conducted with small groups of patients with the rehabilitation programme focussing on improving balance, postural stability, walking and performance of activities of daily living (ADL).

Ni et al. (2016) compared the effects of a power yoga group with a control group who received usual care [29]. The study involved 26 participants and employed a parallel group design. The treatment sessions were one hour, held over 12 weeks, twice per week. The specially designed power yoga programme (YOGA) involved the Vinyasa style, which incorporates vigorous, fitness-based positions. This yoga programme was designed to improve movement speed, muscle strength and power specific to PD-related decrements.

INSERT TABLE 1

Details of study objective, outcome measurements and main findings of the included articles

As seen in Table 2, different appropriate strategies and physiotherapy approaches are designed by the 4 studies, but the goal for all studies was to reduce axial rigidity. To address intervention needs, the main findings of all studies were indicated in terms of improvements of axial rigidity and functional performance. Additionally, improved trunk mobility, turning, balance and gait patterns, as well as reduction in the risk of falls were also mentioned as beneficial effects of exercise-based rehabilitation programmes. The study by Schenkman et al. (1998) [5] measured the primary outcomes, secondary analysis outcomes and physical performance as part of an exercise programme in the early and mid-stages of PD. The results demonstrated that functional axial rotation (FAR) and functional reach (FR) in outcome variables were significantly different when compared between an exercise group with a control group ($p = 0.039$). Whereas, the physical performance measures including supine to stand position and 360-degree turn improved significantly for the exercise subjects ($p = 0.05$). Furthermore, the time to complete a 360-degree turn without a step decreased by almost one second ($p = 0.036$) with a reduction of one step to complete the turn *(p* = 0.010); the time required to complete supine to standing position decreased significantly ($p = 0.033$) when the exercise group and the control group were compared at the end of 10 weeks.

Bartolo et al. (2010) [32] assessed the ROM of the trunk during trunk flexion and lateral bending which was calculated from the upright standing posture using motion analysis. The variables were characterised by the degree of trunk flexion, inclination and rotation. The results showed that, in the upright condition, the exercise group and the control group showed a combination of forward flexion, inclination and rotation of the trunk. There was a significant difference in trunk flexion ($p < 0.01$) and trunk inclination ($p < 0.01$) between the exercise group and the control group at the end of the study.

Stozek et al. (2016) [24] investigated the balance, gait, motor functions and the range of spinal rotation in the lumbar and thoracolumbar. After four weeks, the results showed a significant difference in balance ($p = 0.001$), gait assessment, both 10-metre walk ($p = 0.001$) and 360-degree turn ($p = 0.003$), and motor performance ($p = 0.001$) between the rehabilitation group and the control group. In addition, there was also a significant difference between the two groups in terms of spinal rotation in the lumbar and thoracolumbar ($p = 0.001$).

Ni et al. (2016) [29] evaluated the outcomes of bradykinesia, rigidity, muscle strength and power and QOL through the Parkinson's Disease Questionnaire (PDQ-39). The results showed that the yoga group produced a significant decrease in rigidity score and a large effect size as compared to the control group ($g = -0.64$, $p = 0.001$). Additionally, the yoga group showed better scores in PDQ-39 for the post-test as compared to the pre-test. Significant differences were also seen in mobility ($g = -0.82$, $p = 0.025$), ADL ($g = -0.46$, $p = 0.035$) and the sum score ($g = -0.70$, $p = 0.016$) between the two groups after training.

INSERT TABLE 2

Discussion

The purpose of this scoping review was to identify and summarize the findings of exercise-based rehabilitation programmes that have been used to reduce axial rigidity in people with PD. In accordance with the aims, the inclusion and exclusion criteria were broad [30, 31]. A substantial number of randomised and non-randomised controlled trial studies to reduce axial rigidity in people with PD have been published. However, only four articles met the inclusion criteria for this review. Most studies involved participants with mild to moderate PD. Only one study involved participants with severe PD. Most studies included outcomes that either directly measure rigidity or are based on clinicians' reports on rigidity or physical performance parameters. The exercise group in only one study showed improvement in UPDRS for the rigidity score [29]. An improvement in flexibility is shown in two studies [5, 24], and an increase in ROM outcome is highlighted in two studies [5, 32]. In addition to the positive effects on axial rigidity, three out of four of the studies included also showed positive effects of interventions on improving general functional performance of people with PD (mobility, gait patterns, and reducing the risk of falls) [5, 24, 32].

Among the four selected studies, Schenkman et al. [5] discovered that four weeks of flexibility, balance and functional exercises are most beneficial in improving overall functional abilities. This exercise programme was designed to improve spinal flexibility, coordinated movement as well as balance and function despite rigidity, bradykinesia and motor planning deficits in PD. Furthermore, the study by Ni et al. [29] showed that if a 12-week controlled study of power yoga is applied twice a week, it can significantly reduce rigidity and bradykinesia scores in UPDRS. Yoga exercises have been found to improve health-related QOL by improving gait function and diminishing the fear of falling. Moreover, it has been suggested that a long-term yoga programme may affect psychological sections and cognitive impairment; however, this needs further investigation [29]. Stozek et al. [24] found that a rehabilitation programme focussing on mobility, balance and gait, can improve motor functions in terms of analysed balance and gait parameters and improve a range of trunk rotations in people with PD. However, this study did not address the mechanism of this programme. Nevertheless, from the previous study, it can be assumed that this specific training focusses on problems that people with PD face when learning movements but, under repeated movement trainings, they can memorise their movements, eradicating these problems [33, 34]. Finally, the study by Bartolo et al. [32] aimed to reduce rigidity and improve flexibility and mobility of the trunk. Their main finding indicates that a four-week specific rehabilitation can lead to significant improvements in both axial posture and trunk mobility. The study postulated that these changes are associated with a reduction in the UPDRS motor score, indicating an improvement in clinical status. Unfortunately, this study did not evaluate the functional mobility associated with the main findings.

As evidenced by the very limit number of papers identified by this scoping review, the nature and reporting of studies are likely to provide challenges for therapists aiming to implement interventions into clinical practice. This paucity of evidence is consistent with a general lack of mechanistic insight provided by previous systematic reviews [3, 7]. For instance, Timlinson et al. (2013) conducted a systematic review of 29 studies, examining the effectiveness of physiotherapy, which included 14 studies on exercise for people with PD to improve gait outcomes, functional mobility and balance outcomes, provision data on falls, clinician- rated impairment and disability measures and QOL outcomes [3]. There are three noteworthy observations from this study: 1) the authors identified more studies than the current scoping review, including patients undergoing active treatment and all other physiotherapy treatment techniques; 2) they included all outcomes; and 3) none of the reviewed studies included interventions to improve axial rigidity or address rigidity problems associated with functional mobility in PD. Some literature suggests that levodopa therapy and deep brain stimulation is beneficial in improving axial rigidity [6, 35]. Furthermore, the mechanism of axial rigidity is controlled by neuronal circuits that differ from the ones which control appendicular rigidity. An understanding of the mechanism of axial rigidity and its direct and indirect effects is unclear and makes it difficult to identify appropriate strategies and physiotherapy approaches for addressing this problem [6]. Thus, the information about exercise-based treatment for axial rigidity in people with PD is worth to be explored.

The strength of this scoping review is that it provides the initial steps that need to be taken in this field. A comprehensive review of physiotherapy intervention associated with axial rigidity in people with PD would help researchers better understand common approaches and guide the translation of research into clinical settings. Indeed, this could provide some foundational information to develop a novel, evidence-based exercise-based intervention for axial rigidity problems.

Knowledge gaps

Well-designed, large-scale studies are required to evaluate the benefits of interventions in terms of reducing axial rigidity. Further research is needed to develop the exercise interventions that could ameliorate the axial postural rigidity in the neck, trunk and pelvis which could lead to enhance whole-body coordination which could be assessed using kinematic measurements during functional movement tasks which are potentially important in both clinical and research settings.

Conclusion

The findings of this scoping review indicate that the information about exercise-based treatment for axial rigidity in people with PD is very limited. This review suggests that interventions aimed at reducing axial rigidity yield positive outcomes on functional performance i.e. improve trunk mobility, turning, balance and gait patterns, as well as reducing the risk of falls. However, whether improvements in function due to exercise-based rehabilitation are associated with reduced axial rigidity is unclear. In addition, there is still a lack of evidence for effective exercise interventions to alleviate axial rigidity when conducted in the home setting. Therefore, there is a need for well-designed large-scale studies to elucidate these questions.

***Conflict of interest*:** None declared.

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Supplementary material

Appendix1. The logical structure search for each database**.**

Table 1 Description of included articles.

Table 2 Articles addressing intervention needs and evidence of their intervention.

Figure 1 Study PRISMA flow diagram for the scoping process**.**

Table 1. Description of included articles.

Author (year)	Study location	Population Studied	Interventions
Schenkman et al. **(1998)** (17)	Duke University Medical Center, Durham, North Carolina, USA	- 46 participants: exercise = 23, control = 23 - Male:female, exercise = 18:5, control = 15:8 - Mean age: exercise = 70.6 years, control = 71.2 years - Hoehn and Yahr stage = 2-3 for both groups	- Exercise programme included series of exercises divided into seven graduated stages. The exercises begin in the supine position and progress to standing. - Duration of exercise: 10 weeks
Bartolo et al. **(2010)** (30)	The C. Mondino Institute of Neurology, University of Pavia, Italy	- 44 participants: exercise = 22, control = 22 - Male:female, exercise = 12:10, control = 12:10 - Mean age: exercise = 71.9 years, control 72.2 years - Hoehn and Yahr stage = 1-3 for both groups	-Exercise programme included a 10-minute cardio workout, a 15 -minute stretching exercise, a 15-minute strengthening exercise, a 20- minute gait training, a 15-minute balance training, and a 15- minute relaxation exercises. - Duration of exercise: 4 weeks
Stozek et al. **(2016)** (7)	- The Movement Disorder Clinic, Department of Neurology, University	- 61 participants: exercise = 30, control = 31 - Male:female, exercise =13:17, control = 16:15 - Mean age: exercise = 64 years, control = 67 years	- Exercise programme included breathing exercise, stretching exercise, mobility and functional exercises, postural re-education, balance and gait exercises,

	Hospital in Cracow, Poland. - Department of Clinical Rehabilitation, University School of Physical Education, Cracow, Poland	- Hoehn and Yahr stage = 2 for both groups	music and dance, speech and facial expression therapy. - Duration of exercise: 10 weeks
Ni et al. (2016) (29)	Laboratory of Neuromuscular Research and Active Aging, University of Miami, USA	- 27 participants: exercise 15, control = 12 - Male:female, exercise = 11:4, control = 6:6 - Mean age: exercise = 71 years, control = 75 years - Hoehn and Yahr stage = 2 for both groups	- Exercise programme included the power yoga programme which specially designed for PD to improve movement speed, muscle strength and power. - Duration of exercise: 12weeks

Table 2. Articles addressing intervention needs, outcome measures and main findings.

Author (year)	Study objective	Outcome measures	Main findings
Schenkman et al. (1998) (17)	To improve spinal flexibility and the physical performance of people with PD, particularly those in the early and mid-stage of the disease	- Functional axial rotation (FAR), - Functional reach (FR). - Cervical, lumbar and extremity range of motion - Spine configuration - Turning ability - Six-minute walk - Ten-metre walk	- The exercises learned in each stage were continued throughout the programme, with progressively higher-level activities being added. - Improvements in axial mobility and physical performance can be achieved with a 10-week exercise programme for people in the early and mid-stage of PD.
Bartolo et al. (2010) (30)	To analyse quantitatively changes in trunk posture and motion recorded after a trunk-specific rehabilitation treatment of people with PD	- Kinematic of the trunk in two conditions; 1) flexion, inclination and rotation values in the erect standing posture and	- Identification of PD affected by lateral trunk flexion is important for both therapeutic and prognostic purposes. - An intensive 4-week rehabilitation programme can significantly improve

		2) ranges of trunk flexion and inclination during trunk movements.	trunk flexibility and mobility clinical status.
Stozek et al. (2016) (7)	To assess the effects of a rehabilitation program on balance, gait, motor performance and trunk rotation in people with PD	- Balance using Tandem stance and Pastor test gait - Turning ability - Physical performance - Spinal axial rotation ability	- A 4-week rehabilitation training focussed on various exercises can improve balance, postural stability, walking and performance of activity diary living (ADL).
Ni et al. (2016) (29)	To evaluate the effects of a specially designed power yoga program on bradykinesia, rigidity, muscular performance and quality of life in older people with PD	- The Unified Parkinson's Disease Rating Scale (UPDRS): motor score for bradykinesia and rigidity items - One repetition maximums (1RM) - Peak powers on biceps curl, chest press, leg press, hip abduction and seated calf - Parkinson's disease questionnaire (PDQ-39).	- A 3-month power yoga programme can reduce bradykinesia and rigidity, increase muscle strength and power, and improve self-reported quality of life.

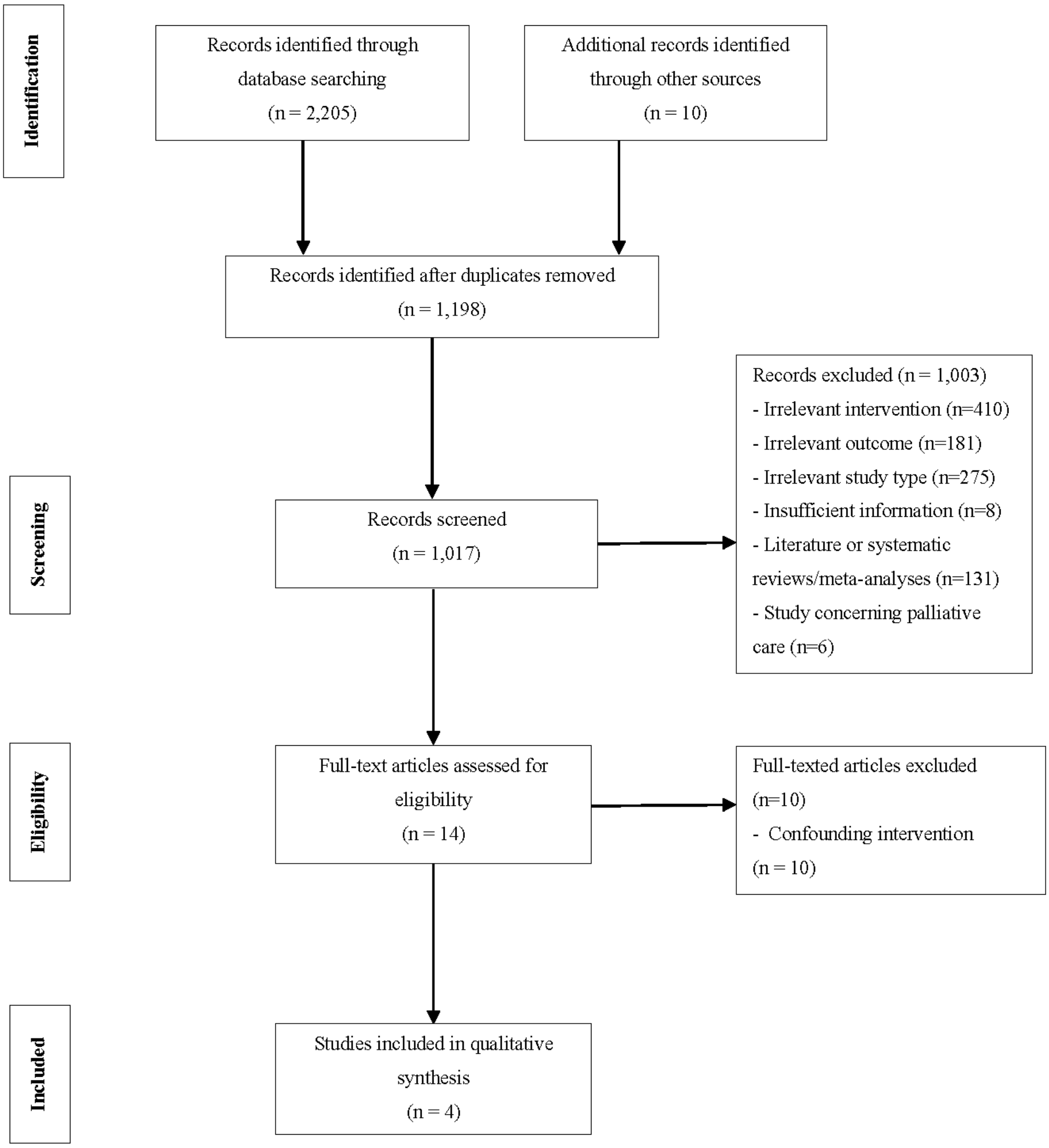

Figure 1: Study PRISMA flow diagram for the scoping process.